# ISSUE OF FOSSIL FUEL RESOURCES AND COAL TECHNOLOGY STRATEGY FOR THE 21ST CENTURY
# - TOWARD THE GLOBALIZATION -

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### 1 INTRODUCTION

Now the Advisory committee for Energy has taken up the security problem of several kinds of energy as the preferred issue and is undergoing revising work of energy supply and demand outlook toward the goal in lese than one year. This work will emboss opaqueness and uncertainty of energy and environment though surrounding condition of energy such as oil price increase is changing considerably. This time at first I will outlook the present state of coal demand, followed by new condition related coal, third one CCT's ability to fixing up coal energy and environment problems, fourth how the condition of coal use will change according to the development of CCT, fifth importance of international cooperation and related issues, and finally noble use of coal in 21 century.

### 2 GLOBAL ENERGY SITUATIONS

(1) The world's primary energy consumption has continued to expand ever since the Industrial Revolution, and recorded particularly rapid growth beginning around 1950. Meanwhile, the world's population has also steadily expanded. It basically doubled over the 100 years following the onset of the Industrial Revolution, and doubled again in the mere space of the 40 years period after 1950, mainly due to growth in the developing economies. It now totals about 6 billion, and is forecast by some observers to reach 10 billion by 2050 (Figure 1).

(2) Such rapid population growth, increase of people's cultural level and acceleration of industrial activities are deeply intertwined with the increased consumption of energy. The total energy demand (in oil-equivalent terms) amounted to 1.3 billion tons, or 0.52 tons per person, in 1950, and is projected to post corresponding figures of 8.0 billion tons and 1.33 tons in 2000. Furthermore, in respect of per capita energy consumption, the developed economies, which account for only about 15 percent of the world population, should occupy nearly 50 percent of the total energy consumption. However the developing economies are anticipated to account for about 60 percent of the increase in primary energy consumption over the years 2010 - 2025.

Primary energy consumption in the member economies of the APEC region, which stood at about 1.7 billion tons in 1995, is forecast to reach as high as 2.9 billion tons in 2010. In this scenario, energy import in the same region would roughly double and hit a level about 40 percent higher than at present in 2010.

The sources of energy are diversifying; oil and coal have been joined in succession by natural gas, nuclear power, and other types of fuel. However, fossil fuels still account for about 90 percent of the supply, and the share occupied by coal comes to about 27 percent. In the Asian region, just over 45 percent of the energy supply depends on coal.

It may be added that the 21st century will presumably see mounting requirements for more efficient utilization of energy and cleaner energy resources.

### 3 WORLD COAL SITUATIONS AND JAPAN'S ROLE

(1) The world's energy sources are diversifying as natural gas and nuclear power join coal and

petroleum. Nevertheless, the world depends for 90% of its energy needs on fossil fuels, and 27% of these are accounted for by coal. In Asia, in particular, coal has a good 45% share. In view of the security of supply in quantitative and economic terms, it is a strong consensus that this situation will not substantially change in the future.

(2) The forecasts for coal in Asia, in particular, (the views expressed at the APEC Coal Flow Seminar held in the Republic of Korea in 2000) are as follows:

a. Coal had a lion's share of 44% in Asia's primary energy mix in 1998. Although its share will fall slightly by 2020, it will still play a major role at around 40%.

Long-term energy economy

On a unit heat value basis: Coal has the lowest price among fuels, followed by petroleum and natural gas. LNG has the highest price.

b. Coal consumption in Asia was 1.5 billion tons in 1998 and is projected to roughly double to 3.0 billion tons in 2020. The two largest Asian economies China and India, alone will account for 80% of coal consumption in Asia. On a world basis, the situation is that US consumption exceeds 1.0 billion tons, and that the three major economies, that is, the US, China and India, will account for two thirds of the world's total consumption.)

c. Major Asian coal import economies in 2020:

Economies importing on a scale exceeding 100 million tons: Japan (There is a possibility that China and India might also become coal importers on this scale.)

Economies importing on a scale exceeding 50 million tons: Japan, Chinese Taipei, Republic of Korea, and India (There is a possibility that China, the Philippines and Thailand might also become importers on this scale.)

d. On the other hand, however, the main coal exporter economies to Asia in 2020 are predicted to be Australia, China, Indonesia, and South Africa. All of these economies are in the process of expanding their coal export capacity and of building their infrastructure. All new development areas tend to move farther a field from the coastal shores to inland regions. It is also expected that mining conditions will become more difficult in the future. The factors cause concern and may not necessarily be possible to achieve coal supply security to meet future demand without problem.

e. Furthermore, due to the environmental problem of recent years there has also been a growing demand for low-sulfur and low-ash coal throughout the world. On a future prognosis, there is no guarantee that Japan will be able to secure the high-grade coal imports so that it has maintained until the present at relatively low prices.

(3) Some major changes can be seen in the structure of the world's coal industry. Thus the oligarchic position of large companies with their coal mining rights will steadily progress toward stronger monopolies, leading to fears of market domination. In China and the former socialist economies, privatization and the move toward giant organizations (as small and medium collieries will be taken over) will run its course, causing apprehension about the way this will affect the supply situation.

(4) In terms of the environmental constraints, there is no telling what effects the sulfur regulations in the production area (USA: 1% or less; China: 3% or less) and the regulations on environmental destruction (ground subsidence, etc.) will have on future development.

(5) In terms of the resource constraints, the outlook is equally uncertain. While the exporter economies are in the process of expanding their infrastructure to meet growing future demand, the coal mining sites are moving away from the coastal region farther inland and will have to cope with more difficult mining conditions, seeing that even South Africa and Australia have gone past their peak. Although coal is the most abundant natural resource it is as finite as any other fuel, and it should not be forgotten that even economically favorable resources are exhaustible. There is no foretelling when the situation will change.

(6) At present, the world's coal market has maintained a low price for the last few years and the general tendency has been that "coal is available in just the desired quantity at the desired time." These so-called "natural resource view" - has disappeared among Japanese user circles and the current

mood is one of unbridled optimism that market prices will remain stable at a low level. This is a dangerous perception. Currently, we have been seeing major change in the European market from the beginning of this year. (20% price increase as compared with September of last year.)

(7) Similarly, the present Japanese long-term demand forecast a rise in coal demand to 124 million tons in 2010. However, the import records for last year already show that imports have reached around 138 million tons.

"The electric power supply target" shows a significant gap between the government forecasts and the data released by the power industry.

Investigation Committee of the Electric Power Industry (Fiscal 1998): Target for 2010
- Nuclear power 45%
- Coal fired thermal power 13%

Fiscal 2000 Electric Power Supply Schedule: Target for 2009
- Nuclear power 35%
- Coal-fired thermal power 21.5%
(Rolling plan of the electric power industry)

(8) The energy and environmental problems are not transparent and uncertain, and coal is no exception.

From a long-term perception, the precarious and unique nature of Japan's energy supply structure has to be considered with the greatest caution, seeing that Japan depends on overseas imports for 90% of her energy supply (for coal, Japan is 97% dependent on imports and is the largest importer economy (share of approximately 30% of world total coal import))

(9) With regard to coal, Japan will have to make further efforts to achieve supply security for coal and to overcome the environmental problems. Under the 6% reduction target for greenhouse gas emission endorsed by Japan in the Kyoto Protocol adopted at COP3 of 1997, 1.8% of this target level are to be met through joint implementation and making use of transactions on emission entitlements. In the future coal development and utilization stages, it will therefore be important to deploy international cooperation projects by dealing this in mind. For Japan as an advanced coal user nation it will therefore be essential to promote international cooperation still further in an endeavor to explore and develop resources and develop and introduce innovative clean coal technology from a global viewpoint for the mutual benefit of both the producer and consumer economies.

## 4 ASSESSMENT OF ENERGY RESOURCE

Of primary importance in any view of the energy outlook in the 21st century is the prospect of a depletion of the conventional resources of fossil fuels, which account for 90 percent of the world's total commercial supply of energy.

### 4.1 Reserves and comprehensive assessment

Table 1 shows the amount of reserves of each type of conventional energy resource covered by current assessments. This table is based on current proven reserves, and could vary greatly depending on two factors: the discovery of new reserves through exploration and an increase in the recovery ratio. Coal may be regarded as offering advantages in respect of supply stability and economic merit, since its deposits are fairly evenly distributed and that the remaining life of recoverable reserves of other types of energy resources is less than 100 years in every case. In most forecasts, the peak of conventional oil production is expected to arrive early in the 2000s. If so, coal would presumably assume even more importance. According to the material of G8 energy ministers meeting (prepared by IEA), it is indicated that oil production see a peak and turns to decrease when about a half of ultimate recoverable reserve was produced, by a experimental rule of oil production experience having area. With this rule, a peak of conventional oil production is expected to come between 2010 ~ 2020 (Figure 2). As a recent example, the expectation that non-conventional oil will come out in about 2030, published at APEC coal flow seminar held at Kyongju, Republic of Korea.

## 4.2 Economic and technical Assessment of Coal Resources

As shown in Figure 3, the amount of recoverable reserves for each type of energy resource could essentially increase depending on technological advances and price factors. In the case of coal, the R/P ratio (table 1) should be the amount of reserves that are actually recoverable. However, it may be difficult to carry out a highly accurate calculation of R/P, as the reliability of data varies somewhat depending on the economy or region. This is coupled with constraints in areas such as technology, safety, economic merit, and environmental considerations. To date, the supply of resources has been from reserves that are most conducive to development in both technical and economic terms, and the R/P for coal that could be economically recovered at the current prices is thought to be considerably lower. The coal resources bequeathed to the next generation could be characterized by a gradual rise in the difficulty of development and decline in the quality of economically feasible coal. A major task for the future is to find a way to surmount this problem with development and utilization technology. For example, on the coal resource in New South Wales state, which was published in Japan-Australia workshop, held in 1998, it is said that economically winnable coal resource is really only 6% (Figure 4, 5)

## 4.3 Expansion of the Potential of Coal Resources

Essentially, resources are assets to be shared by all humankind in common; they do not belong exclusively to some economies or to the present generation. For future generations, we must not only make the most efficient use of our non-renewable, finite coal resources but also work to expand and extend their potential. I see four requirements in this connection.

The first is ongoing exploration and discovery to add new reserves to the existing stock of reserves already proven.

The second is an increase in the recovery ratio, which is extremely low today, at about 20 percent. The recovery ratio for oil dramatically improved when steps were taken to apply artificial pressure instead of depending entirely on the wells own flow for extraction. Although there has not been much of an increase in the original reserves of oil, this substantially increased the potential in both quantitative and economic terms. The same kind of challenges is expected for coal.

The third is an expansion of the total coal resources. This can be done by recovery and use of currently untapped and underused resources, such as coalmine gas, of which only about 5 percent is utilized worldwide, and coal preparation sludge.

The fourth is a broadening of the range of types of coal utilized as utilization technology advances and types of use diversify. Among the conventional types of coal resources, there are also expectations of expanded exploration and refined use of low-rank and low-grade coal, which are varieties of brown coal, and sub-bituminous coal. Furthermore, like the oil industry, which has positioned oil shale and tar sand as futuristic resources, the coal industry has an enormous amount of non-conventional resources in such forms as peat.

In any case, the current official figure of about 1 trillion tons for recoverable reserves (R/P, 200 years) could surely be increased substantially through continued exploration and technology development for full exploitation of total coal resources.

## 4.4 The Greenhouse Effect and Need for Life Cycle Assessment

If no technical countermeasures are taken, the combustion of coal results in the emission of large quantities of carbon dioxide gas, which is a cause of the greenhouse effect behind global warming. Comparison with other fossil fuels in respect of the level of CO2 emission is said to yield the ratio 5 (coal): 4 (oil): 3 (natural gas). Nevertheless, the comparison should be based on the level of greenhouse effect throughout the life cycle, i.e., inclusive of methane gas emission and considering the phases of production and transportation as well as that of combustion. On this basis, some assessments place the level for coal at 20 - 30 percent as high as that for oil and natural gas. Such life-cycle assessment deserves to be duly authorized.

# 5 OUTLOOK FOR COAL ENERGY IN THE 21ST CENTURY AND THE GLOBALIZATION OF TECHNOLOGY

## 5.1 Basic Perspectives

Coal ought to be accorded a vital status as one of the world's core energy resources for the 21st century. As such, we should make a strict commitment to the expanded utilization of coal. The major tasks to this end are:

(1) assurance of a stable supply of good quality and economical coal; and

(2) conquest of environmental problems (especially those on a global scale). In other words, prospects may hinge on the ability to discharge these two tasks.

While there is a disposition to prefer fossil fuels with comparatively low CO2 emission levels in order to meet the immediate targets for reduction of greenhouse gas emissions, it must be noted that reserves of coal are much more plentiful than those of oil and natural gas, and that it is important to deploy utilization strategies which make up use of the properties of each fuel type in schemes of mutual complementation. For coal, there still remains ample margin for development of technology to achieve cleaner use. Active promotion of such development would appear to be the proper orientation of policy on coal.

## 5.2 Overall Strategy

I have long advocated what I call the "Triangle Strategy" (Figure 6) for the resolution of the present problems in the aspects of supply and the environment. The underlying idea is that the three factors, i.e., resources (supply), utilization (demand) and the environment, should be regarded as forming a single interrelated triangle instead of viewed in separately from each other. Consequently, they should be addressed through a coordinated effort by all segments of the so-called coal chain. In the triangle strategy, each of these factors must be considered in relationship with the others.

a. Relationship between resources (supply) and utilization (demand). Whereas the supply side wants to see expanded utilization of coal on the demand side, the demand side wants a stable supply of good quality coal at reasonable cost.

b. Relationship Between resources (supply) and environment. What the supply side desires of the environment side is an enlargement of the areas where mining is permitted and related deregulation. Conversely, the chief environmental expectation for the supply side is for development methods that are friendly to the earth.

c. Relationship between the utilization and environment sides, the former is seeking avenues of coexistence, and the latter, provisions for earth friendly harmonization.

The crucial element for resolution of conflicts in this triangular relationship is the globalization of technology, which should be jointly promoted by the producing and consuming economies. In other words, we must encourage the international sharing of resource and technical information, the execution of international technical exchange and joint proving, and international programs of human resource development. It may also be observed that the topical issues in coal technology are of a diversity, complexity, and scope that go far beyond the traditional realm of simple engineering. This will make it all the more necessary to pursue fusions with technology from other sectors and approaches that integrate science and technology.

## 5.3 Technical Tasks for Coal and Keys to their Solution

In the interest of expanded utilization of coal, it is the duty of the supply side to provide for a stable supply that is both of good quality and economical, and for utilization to be both efficient and clean.

(1) Basic concepts

- More fully
- More safely

- More reasonable prices
- More environment-friendly

(2) Expansion of the potential of coal resources and related issues

For the supply side, the key to expanding the coal resource potential lies in overcoming both the resource constraints associated with mining and socio-economic conditions, and the environmental constraints associated with increased coal consumption, coal mining, and coal quality.

1 In the event of supply surplus, prices continue to fall rapidly, and this widens the price gap between coal and other types of energy. Under these circumstances, there are concerns about the hindering of sound development of the coal mining industry, a stagnation of new projects of exploitation and technology development, and the future supply stability.

2 Assurance of the economical coal supply and technical issues

- Improvement of technology for resource exploration and assessment, and promotion of further exploration
- Determination of changes in coal quality and expansion of coal types for utilization
  - Development of technology for refining and storing low-grade coal
  - Expansion of total resources (effective utilization of untapped or underused resources)

3 Improvement of recovery ratios (and resolution of technical problems related to thick-seam mining in particular)

4 Establishment of a high efficiency mining system ensuring high levels of stability and safety at low cost

- Increase in the speed of roadway development
- Measures for movement toward underground mining, with an emphasis on the establishment of a crisis management system for deeper-level mining, including:
  - Underground communications
  - Gas management
  - Strata control
  - Promotion of occupational health

Clean coal issues

- Establishment of closed systems for drainage
- Removal of hazardous substances
- Refining of low-grade coal

Development of innovating mining technology

- Establishment of mining system for a thick coal seams
- High-production hydraulic mining technology
- Fluidization technology, including underground gasification, etc.

Approach to global environmental problems

- Recovery and utilization of methane gas
- CO2 fixing (underground)
- Early reforestation for the rehabilitation of open-pit mining
- Harmonization with nature
  - Countermeasures for ground subsidence, etc.

(3) Issues on the side of coal use

On the use side, the top priority is an improvement of combustion efficiency. Besides promoting further development of clean coal technology (CCT) as needed for environment-friendly forms of utilization, we must build programs of international cooperation that encompass the transfer of such technology and span both the "hard ware" and "soft ware" aspects.

Expanded use of more types of coal

High-efficiency use

- Establishment of high-efficiency combustion technology

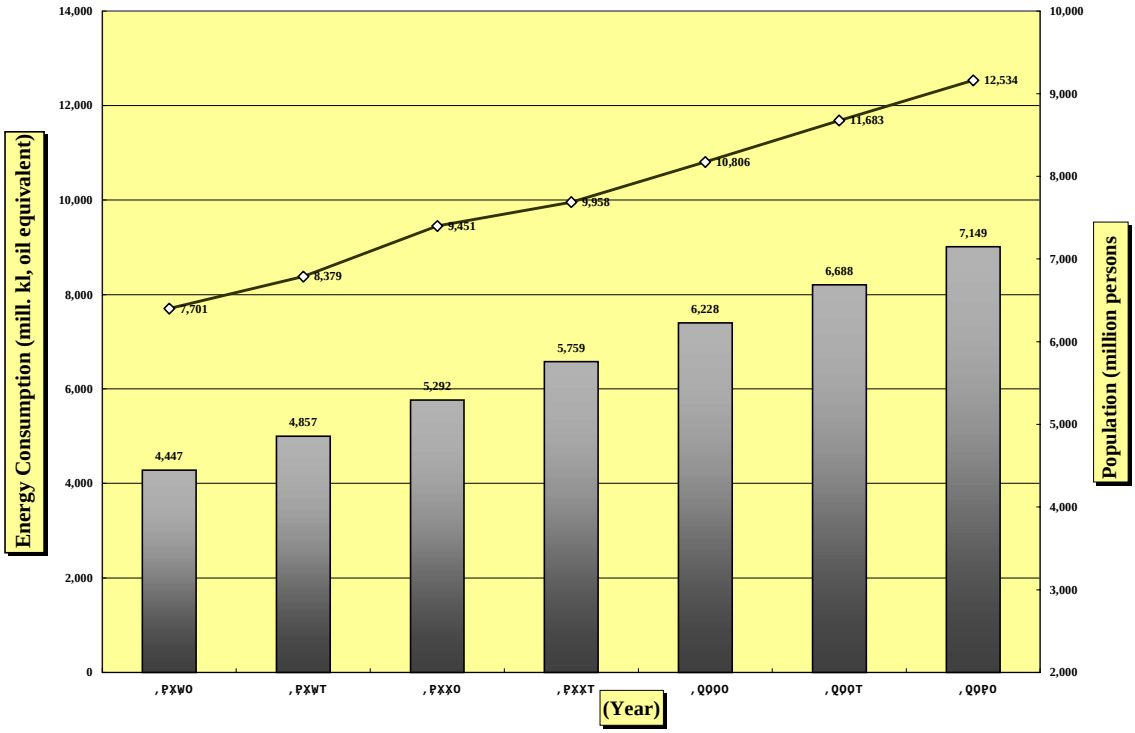
- High-efficiency hybrids and composites

Coal fluidization
- Slurries
- Gasification (IGCC, DME, hydrogen)
- Liquefaction

Zero-emissions setups (ultimate objective)
- Switch from an open cycle to a looped cycle
- CO2 separation and fixing

## 6 CONCLUSIONS: COAL IN THE 21ST CENTURY (TOWARD A NEW COAL AGE)

To achieve "noble use" of coal, parties on all sides must strive for optimal utilization of coal resources in environment-friendly modes as their common goal, and resolutely take up the challenge of all requisite tasks under the following watchwords:
- Higher levels of cleanliness
- Greater efficiency
- Higher economic merit
- Greater ease of use




Source: International Energy Outlook, EIA & World Populations, 1992

**Figure 1 World Trends and Forecasts in the Energy Consumption and Population**

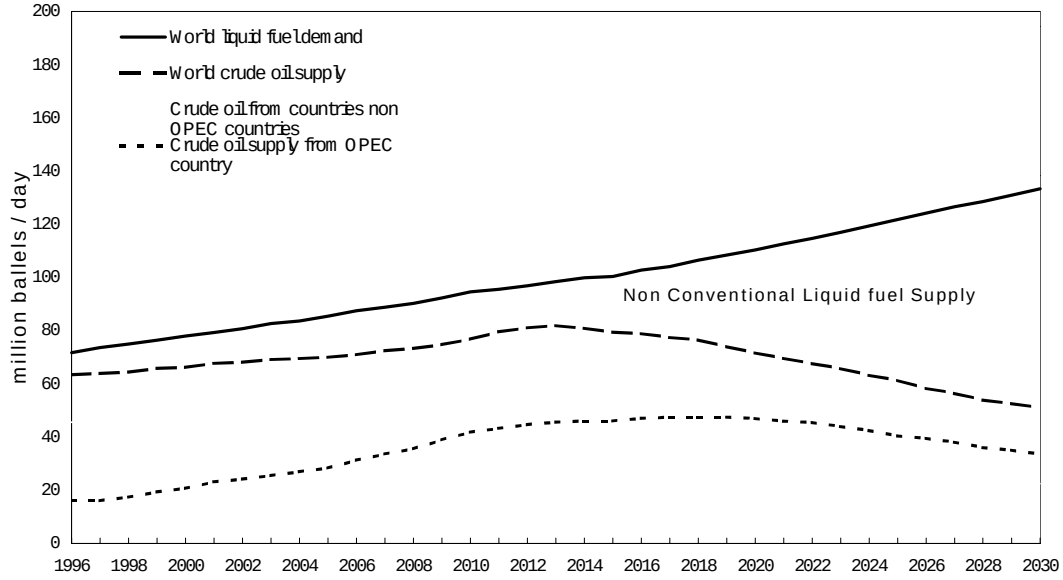



**Figure 2 Outlook of Oil Supply (1996 – 2030)**

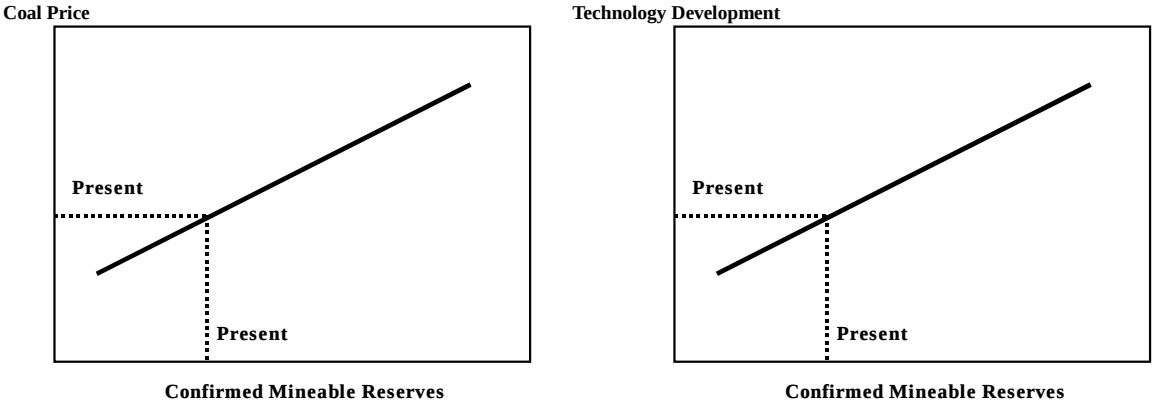



**Figure 3 Confirmed Mineable Reserves VS. Coal Price and Technology Development**

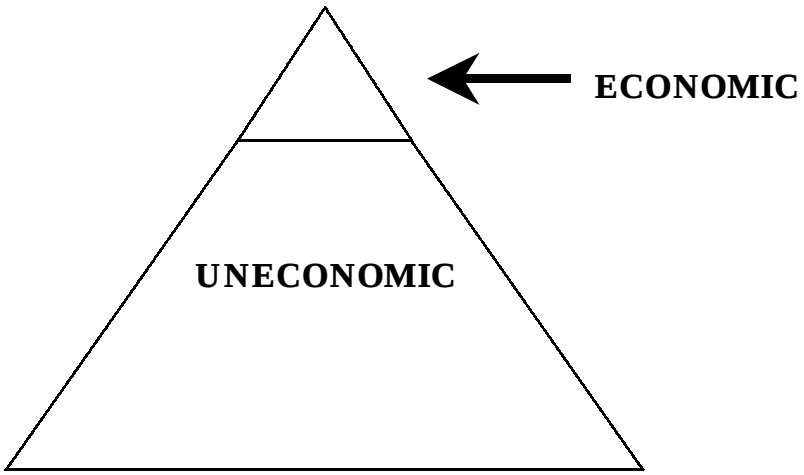



**Figure 4 Coal Resources Pyramid**

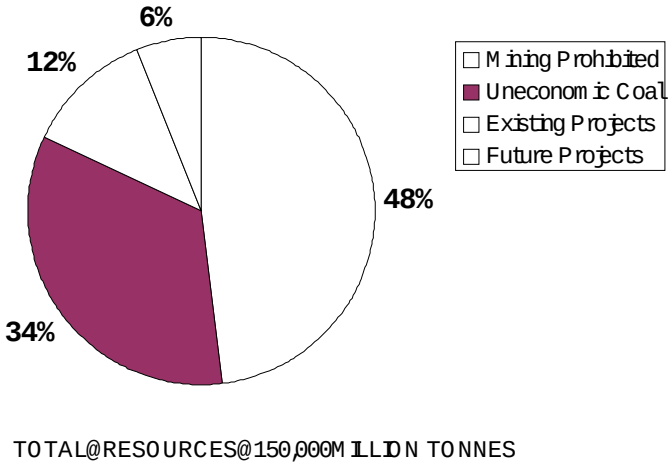
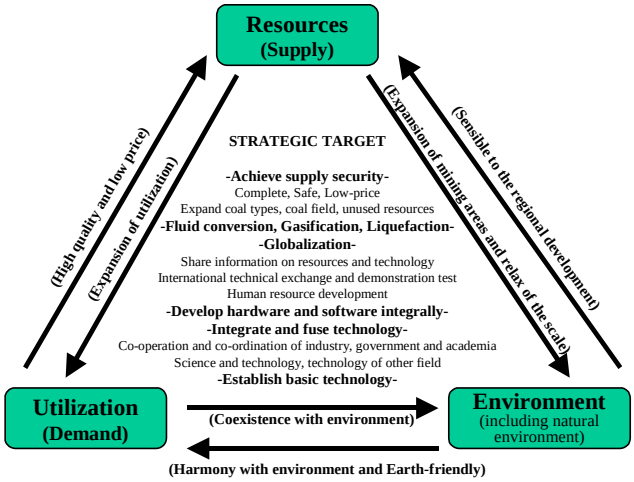



**Figure 5 NSW Coal Resources**




**(Problem and Solutions : Resources)**

1. Expand coal resources potential - Breakthrough to overcome the resources and environment limitations and new development.
   - Advancing in exploration and development of more sophisticated exploration technology
   - Establish assessment methods.
   - Determine changes in coal quality and expansion of the scope of coal types.
     Upgrade and storage low-rank coal
     Expand total resources - utilize unused resources - methane, sludge etc.
   - Improve recovery ratio.
     Develop and establish new mining system - top coal caving, highwall mining, high-production hydraulic mining, underground gasification
     Develop and establish mining system under sever conditions - deep mining, thin or thick seam mining, unmanned mining
2. Establish high-efficiency, low-cost, stable and safe mining system.
3. Progress to increasing depth (gas and strata pressure) and other measures.
4. Develop clean coal.
   - Reduction of Ash, SOx, NOx, $CO_2$ emission
   - Upgrade low-rank coal
   - Measures against toxic substances
5. New measure to prevent global warming.
   - Methane gas recovery and utilization
   - Accelerate greening/planting (afforestation) schemes
6. Crisis management system.
7. Develop revolutionary, innovative technology (Fluid conversion technology, including underground coal gasification).

**(Problem and Solutions : Utilization)**

1. Establish combustion system suitable for various coal types.
   - Low-rank coal
   - Anthracite
2. Increase in combustion efficiency and other measures
   - Combine energy saving and resource saving
3. Improve in economic performance and complex system development.
   - Establish synthetic and complex using system
4. Expand use of conversion technology.
   - Liquefaction
   - Gasification (including hydro-generation)
5. Utilize unused resources.
   - Methane gas
   - Coal preparation sludge
   - Other byproducts
6. Reform and its applications.

**(Problem and Solutions : Environment)**

1. Develop the conventional pollution prevention methods to a higher level of sophistication.
2. Promote environmental measures on a global scale.
3. Monitor of flexible measures and establishment of evaluation methods.
4. Mining limitation and measures to protect the natural environment, symbiosis/coexistence between nature and industry.
   - Ground settlement/subsidence
   - destruction of forests (including mangroves)
5. Utilize and treat ash effectively.
6. Utilize industrial byproducts effectively.
7. Develop other coal complexes.

**Figure 6 21st Century Coal Technology Strategies – Triangle Concept**

## Table 1 Reserve of the Different Resources

| | | Petroleum | Natural gas | Coal | Uranium |
|---|---|---|---|---|---|
| (Note 1) Whole World Confirmed Mineable Reserves (R) | | (January 1, 1998) **1,019,546** million barrels | (January 1, 1998) **143.9471** trillion $m^3$ | (End of 1996) **984.2** billion tons | (Jan, 1997) **4.36** million tons |
| (Note 2) Whole World Annual Production (P) | | (1997) **64,940** thousand barrels/day | (1996) **2,220** billion $m^3$ | (1993) **4.65** billion tons | (1996) **36,000** tons |
| Reserve/ Production Ratio (R/P) | | (1997) **43.0** years | (1996) **61.6** years | (1996) **211** years | (1996) **73** years (Note 3) |
| Source | (Note 1) | Oil & Gas Journal (December 29, 1997) | Oil & Gas Journal (December 29, 1997) | World Energy Council (1995) | OECD/NEA/ IAEA (1997) |
| | (Note 2) | Oil & Gas Journal (December 29, 1997) | Oil & Gas Journal (March 10, 1997) | | |

Source: MITI

Note 3: On uranium, annual production is under annual demand (60 thousand tons) because there is a plenty of storage. Therefore R/P is given by confirmed mineable reserves divided by annual demand.